Factors Influencing The Temporal And Spatial Variability Of The Textural Characteristics Of Event-Scale Strata On The Eel Shelf

Dr. David E. Drake, President
Drake Marine Consulting
1711 Quail Hollow Road
Ben Lomond, CA 95005
Phone: 831-336-1127; Fax: 831-336-8802; Email: dd4dmc@earthlink.net

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LONG-TERM GOALS

The overall goal of the STRATAFORM project is to advance our understanding of the development of stratigraphic sequences on continental shelves and slopes. Part of this understanding comes from detailed measurements of the characteristics of event-scale strata that may be formed or modified during river floods and intense storms. Our research is directed toward providing data on the grain-size characteristics of event-scale strata that can be related directly to storms or floods observed during STRATAFORM. This information provides a "yardstick" with which to examine older sediment units in long cores with the objectives of understanding modes of deposition, strata preservation and, potentially, any variability or long-term trends in climate and resulting river discharges.

OBJECTIVES

Specific objectives of this project have been:

1) Develop a detailed characterization of event-scale strata on the Eel River shelf, with an emphasis on the texture and grain-size of the event beds.

2) Link the event-scale strata directly to the process (e.g., flood or storm) that formed it.

3) Document and understand the mechanisms, rates and effects of early diagenesis of the event layers.

4) Use time-series observations and samples to develop skill at predicting the preservation potential of flood and storm event layers.

5) Use time-series sediment cores to monitor changes in the sediment distribution on Eel shelf and especially to track the redistribution of flood event material on time scales of months to years.

6) Determine the magnitude and causes of spatial variability in the characteristics (especially grain-size) of mid-shelf strata.

7) Develop an event-scale bed "signature" that can be used to identify beds that have made it through the surface bioturbation layer and may be found in long cores and in ancient strata (e.g., in the nearby Plio-Pleistocene Rio Dell Formation).

8) Provide detailed grain-size profiles to help interpret the x-radiographs of box cores collected by Drs. Wheatcroft and Borgeld and also the bulk density profiles generated by the new Geotek whole-core logger.

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14. ABSTRACT
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APPROACH

A large collection of sub-samples of sediment cores is available for various shelf sites from February 1995 through April 2000. We have routinely collected samples of the surface (0 - 1 cm) sediment at regional sites. At selected sites (e.g., the O - line shelf stations) we have taken multiple sub-cores of box cores and also collected piston cores. Rapid response sampling has been used to collect event layers soon after they were formed.

The great analysis speed provided by the Coulter Counter Multisizer II electronic particle size instrument, and it's ability to analyze small samples, allows us to examine core sediments at closely - spaced downcore intervals (1 cm or less). This is important because event-scale strata are typically much less than 5 cm thick on this shelf and on most other shelves (see for example, Wiberg, 2000).

WORK COMPLETED

During FY 01, the final year of the STRATAFORM project, Dr. Drake has focused on:

1) continuing to evaluate recent, EPA-funded sediment production studies in the coastal watersheds of northern California, including the Eel River basin. Our goal has been to estimate the impact of human activities on sediment production in the Eel watershed during the past 50 years of increased logging and grazing.

2) finishing our analysis of event-layer bioturbation and bed preservation potentials.

3) tracking the redistribution of flood sediment on the shelf and relating that redistribution to environmental factors (e.g., wave and current energies).

4) using our new knowledge of the modern Eel shelf to examine event-scale strata in older sediments on the present shelf and also in the Rio Dell Formation, a Plio-Pleistocene analogue to the modern Eel shelf (see Leithold, 1989).

The final push to complete our STRATAFORM studies resulted in eight poster presentations, 4 at the Fall 2000 AGU and 4 at the 2001 Chapman conference in Puerto Rico, and also two co-authored papers (Goff et al., in press, *CRS*; Sommerfield, Drake and Wheatcroft, submitted to *Geology*).

RESULTS

Important results for FY 01 are as follows (keyed to the completed tasks in previous section):

1) Table 1 clearly shows that sediment production related to anthropogenic activities (e.g., logging and logging roads, grazing and other agricultural activities) in the steep, rugged watersheds along the northern California coast is highly significant. On average for the post-WW II time period the anthropogenic load has been about 40 - 50% of the total load. To put this into perspective, if one conservatively assumes that the non-natural load is 33% of the total Eel River load, which is about 18 million tons/yr, then the anthropogenic load is 6 million tons/yr. Accordingly, since 1950, human activities have produced an amount of excess sediment equivalent to almost *two* 1964 flood events, or *ten* 1995 floods. The 1964 flood was a 300-400 year event that delivered a record total of about 160 million tons of sediment to the coast in one season. Since about 1950, the anthropogenic sediment load has contributed significantly to increasing the average sedimentation rate on Eel shelf, increasing the average thickness of flood event beds and thereby improving the

chances that these layers will be preserved. In addition, the excess sediment in the watershed also increases the likelihood that flood events will produce high concentration fluid muds on the inner shelf. It is important to weigh these new factors when interpreting and/or modeling ancient strata on Eel margin or on other shelves with similarly large anthropogenic impacts.

Table 1. The present-day anthropogenic sediment load in seven coastal watersheds of northern California. (USEPA Reports 1999a,b)

Watershed	Anthropogenic Sediment Load (as % of the total stream sediment load)
South Fork Eel River	**46%**
Van Duzen River (another tributary to Eel R.)	**23%**
Redwood Creek	**70%**
Noyo River	**35%**
Navarro River	**33%**
Garcia River	**55%**
South Fork Trinity River	**35%**

2) the time-series of box cores at many sites on the Eel shelf has allowed us to monitor the changes in event-scale strata from February 1995 through April 2000. Event beds are rapidly degraded by bioturbation, losing their visual aspect within just a few years. However, as shown in **Figure 1**, the grain-size profile will often retain an event layer signature that can be used to identify layers in longer cores and/or in the ancient outcrop record.

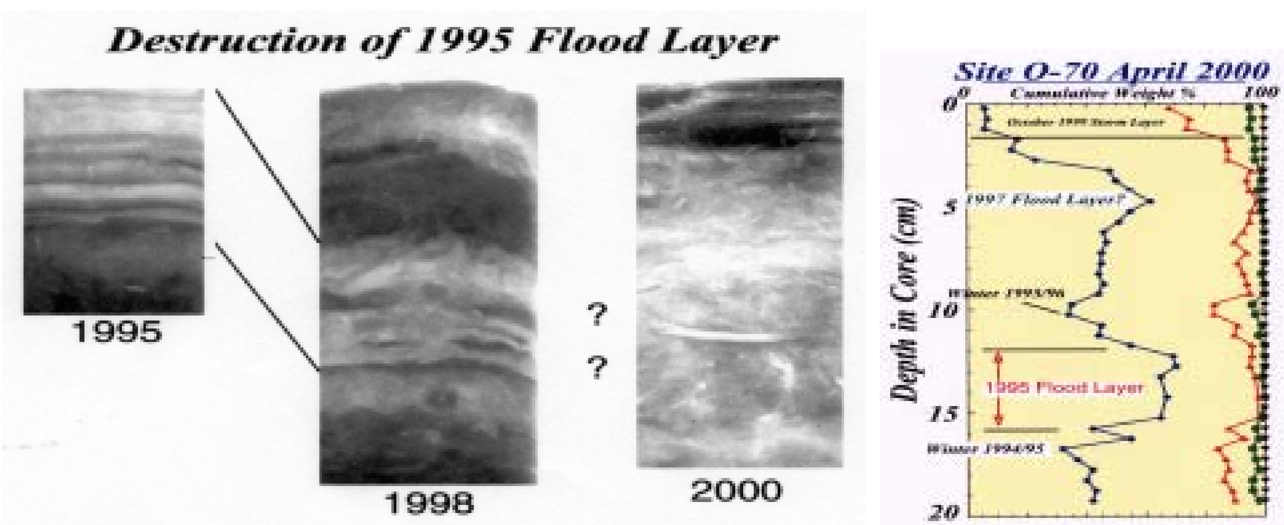

Figure 1. The X-radiograph images (courtesy of Dr. Jeffry Borgeld) from Site O-70 on Eel shelf show the progressive destruction by bioturbation of the visual aspects of the 1995 flood layer. The grain-size profile at the right shows the cumulative weight % of sediment beginning with the 0 - 20 micron fraction (in blue). The finest fraction is an excellent indicator of flood layers on the central part of Eel shelf (Drake, 1999)

By assembling all of the grain-size signature data for many sites on Eel shelf we have been able to prepare the preservation potential curve shown in Figure 2. The data demonstrate that unusually large

sedimentation rates or extremely thick event beds are required to guarantee preservation. In fact, we have found that preservation is most often related to the timing of events; that is, a second event burying an earlier event is one of the most likely preservation mechanisms on Eel shelf. This has also been found to be the case in the Rio Dell Formation (Drake et al., 2001). The preservation potential curve in Fig. 2 would shift up/down depending on whether the local bioturbation rate is higher/lower than the average on Eel shelf.

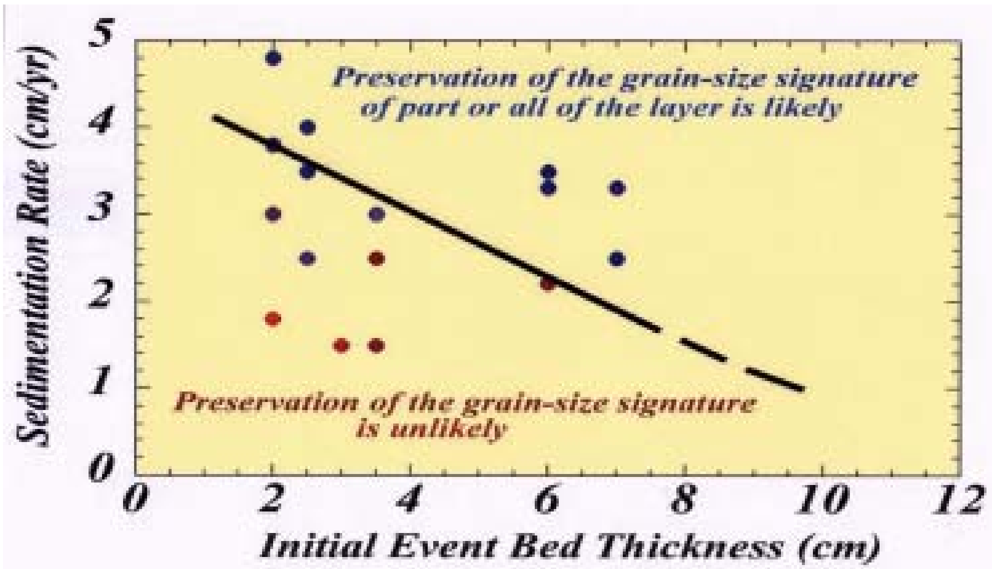

Figure 2. Preservation likelihood for event strata on the middle of Eel shelf. Because the sedimentation rate on Eel shelf is typically well below 1 cm/yr, preservation of beds is not likely, unless they are extraordinarily thick or are followed soon by more events.

3) Redistribution of flood sediment was monitored with time-series box cores on the O-line and it links very well with the higher levels of wave energy in the winters following the 1995 and 1997 floods. The cross-sections below demonstrate the redistribution of sediment to the outer shelf after several years of reworking by winter storms (Figure 3). The importance here is that the Eel shelf environment cannot readily be labeled as either "storm-dominated" or "flood-dominated"; it is a mixture of both.

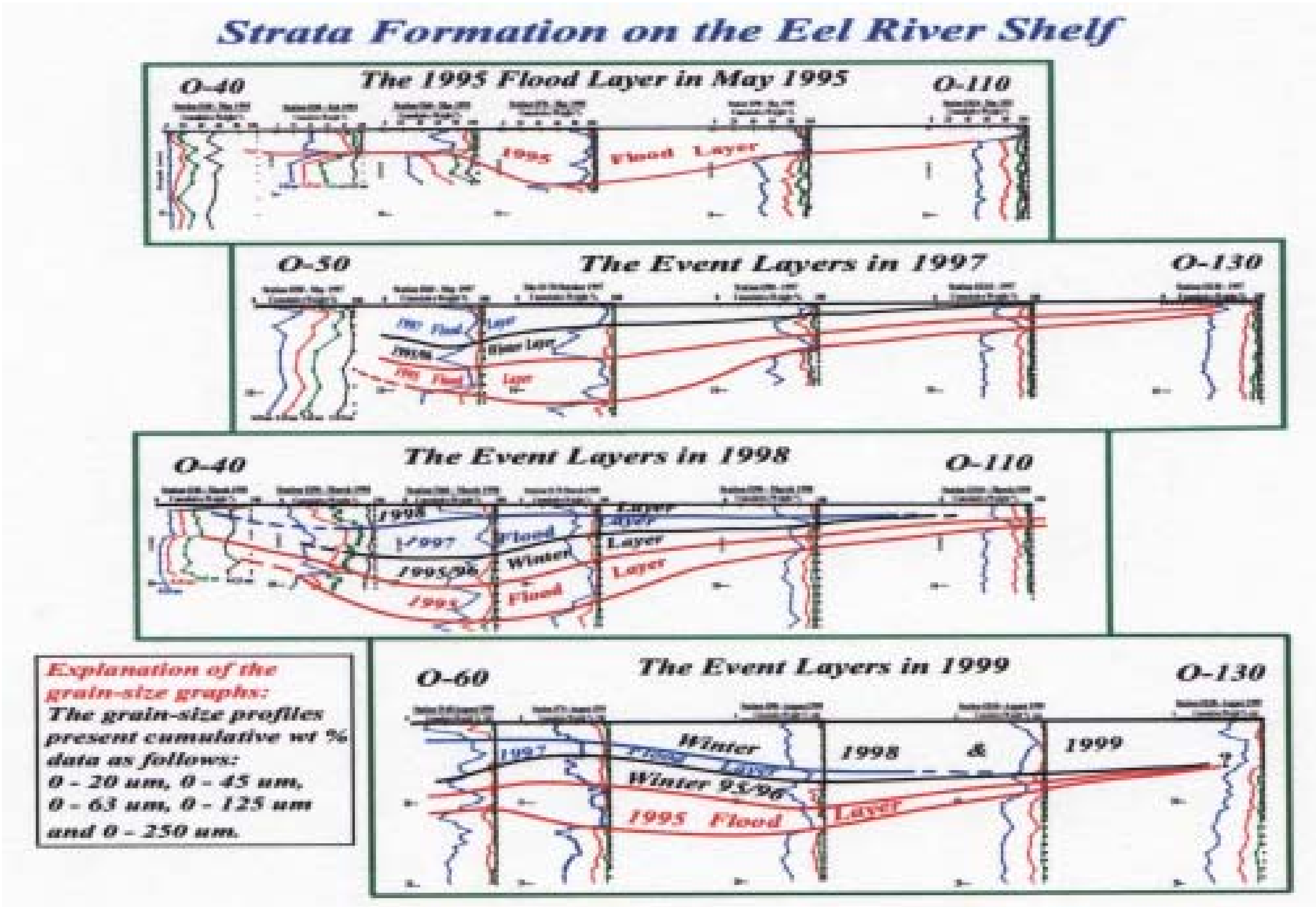

Figure 3. Redistribution of flood sediment to the outer shelf following initial deposition at 60-70 m. The peak period of redistribution correlates well with bottom tripod observations of wave energy and current directions collected by University of Washington researchers (Sternberg and J. Guerra).

4) our final effort in FY 01 was to examine the Rio Dell Formation in the light of our STRATAFORM studies on the modern shelf. The results, presented at the Chapman conference in Puerto Rico, were that the strata of the Rio Dell Fm are entirely compatible with the strata on the modern shelf, *except* that we did not find any equivalents to the thick (10 - 40 cm) Fleener Sands (Leithold, 1989) in the modern setting. The answer to this puzzle awaits the long coring effort proposed for the Eel margin.

IMPACT/APPLICATIONS

Future impacts related to our findings are: 1) broad changes in the character of shelf sediment can occur on time scales of hours to days during and following floods and storms. Rapid response sampling *and* much more sophisticated *in situ* sampling are required to understand these changes. 2) the physical properties of the bed (e.g., texture, compaction and cohesiveness) must be known if modeling of sediment transport is to be accurate. 3) our understanding of the stratigraphic column depends on the quality of the standards that we have. If recent systems are different because of human activities or other factors, these influences must be quantified through careful study of long cores. Strataform research has spot-lighted the critical need for high-quality 50m - 100m cores on the margin. 4) we have demonstrated the usefulness of very detailed profiles of grain-size in cores. Grain-size data

at downcore intervals of 0.5 cm can reveal strata that are not detected by x-radiographs or Geotek whole-core logs.

TRANSITIONS

Our results are fundamental information for the modeling components of the Strataform project. Drs. Harris, Wiberg and Swift have used our data on flood layer modifications, both as inputs to begin their modeling predictions but also as "ground-truth" to check their results. Based on our data, they have modified their approach to incorporate bed cohesiveness more prominently on the mid-shelf. Moreover, our strata preservation studies have inspired Dr. Wiberg to design experiments to examine cohesiveness in fine-grained beds. Spatial scales are also important for the stratigraphic modelers and the spatial variability results (Goff et al, 2000; and in press) will be useful.

The studies of time and space variability have been important as a catalyst for new ideas on how to properly sample events that may last for only a few hours or days. I am sure that new in situ sampling methods, such as those proposed by Dr. Wheatcroft, will be the outcome of this work.

RELATED PROJECTS

The seabed sampling components are all interrelated and data exchanges occur frequently. The research of Drs. Wheatcroft, Borgeld, Drake and Sommerfield are especially related because of the common objectives of providing full descriptions and understanding of the strata on Eel shelf. This cooperation has resulted in a number of joint papers (e.g., Sommerfield et al., submitted; Goff et al., in press). Dr. Drake also contributes to the sediment transport modeling efforts of Drs. Wiberg, Harris, Fan and Swift; journal articles are planned that will relate the event-scale strata to the waves and currents on the shelf. Finally, the spatial variability study has involved close cooperation with Dr. Goff (UTIG).

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